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(54) **METHODS UTILIZING TRIANGULATION IN METROLOGY SYSTEMS FOR IN-SITU SURGICAL APPLICATIONS**

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CPC ***G01B 11/14*** (2013.01); ***A61B 5/1076*** (2013.01); ***G01B 11/02*** (2013.01)

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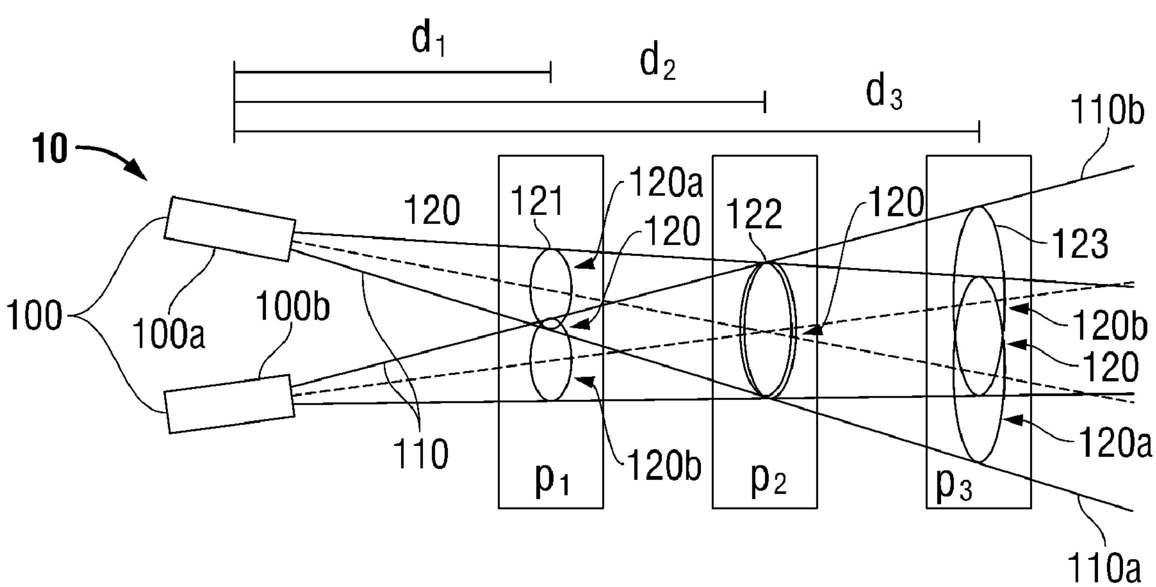
(57) **ABSTRACT**

A first metrology method includes the steps of projecting a first image and a second image, aligning the first image and the second image to form an aligned image of a known size, and determining a dimension of a target object by comparing the aligned image to the target object. A second metrology method includes the steps of projecting a first image and a second image, aligning the first image and the second image to form an aligned image of a known size by synchronously adjusting a zoom factor for projecting the first image and an angle for projecting the second image, and determining a dimension of a target object by comparing the aligned image to the target object.

10 Claims, 3 Drawing Sheets



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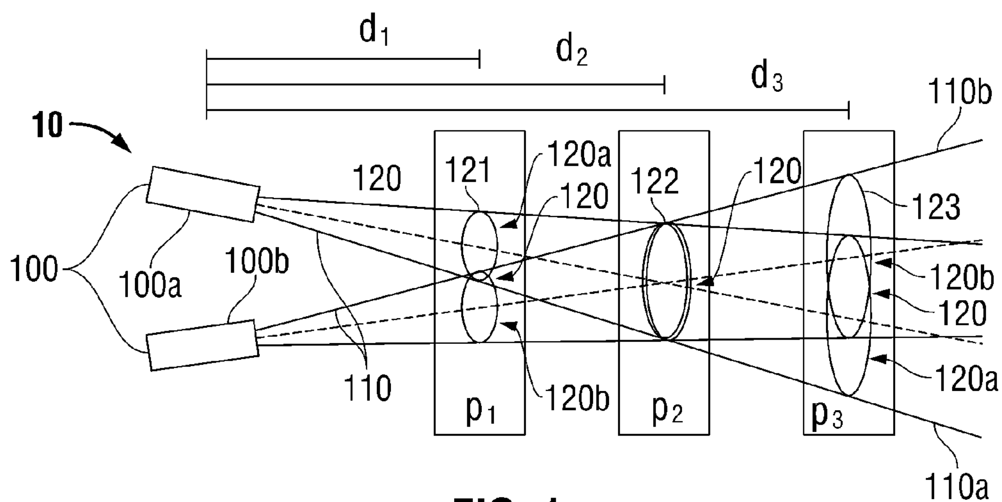
d1
d2
d3
10
110b
120
121
120a
120
122
120
123
100
100a
100b
120b
120
110
120b
p1
p2
p3
120a
110a

FIG. 1

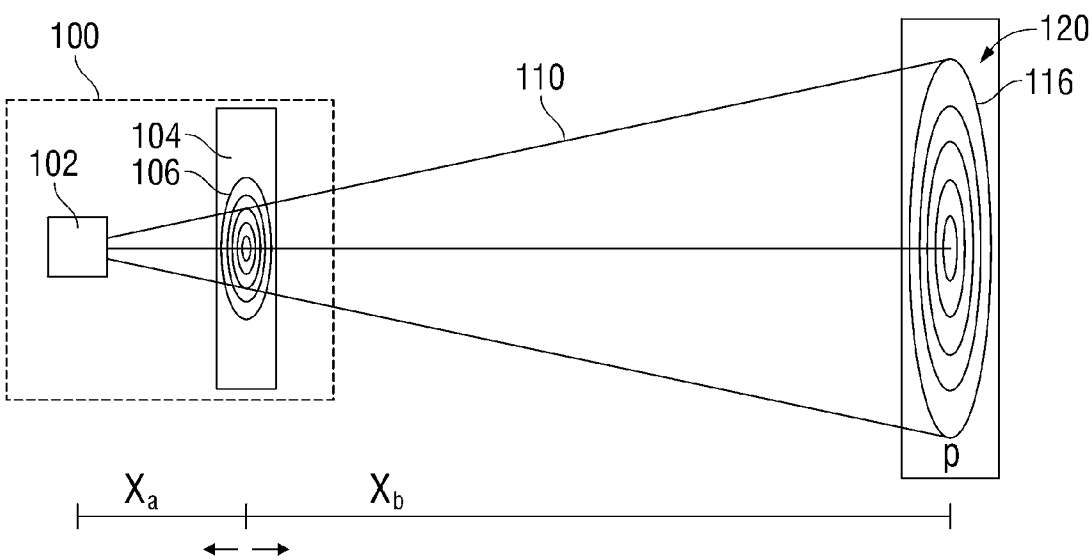
100
120
110
116
104
102
106
p
Xa
Xb

FIG. 2

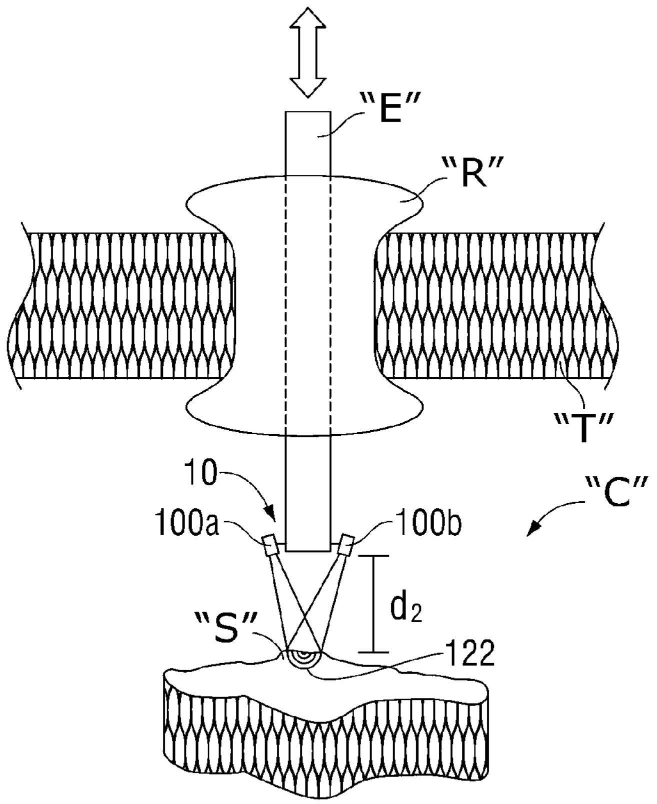
"E"
"R"
"T"
10
"C"
100a
100b
d_2
"S"
122

FIG. 3

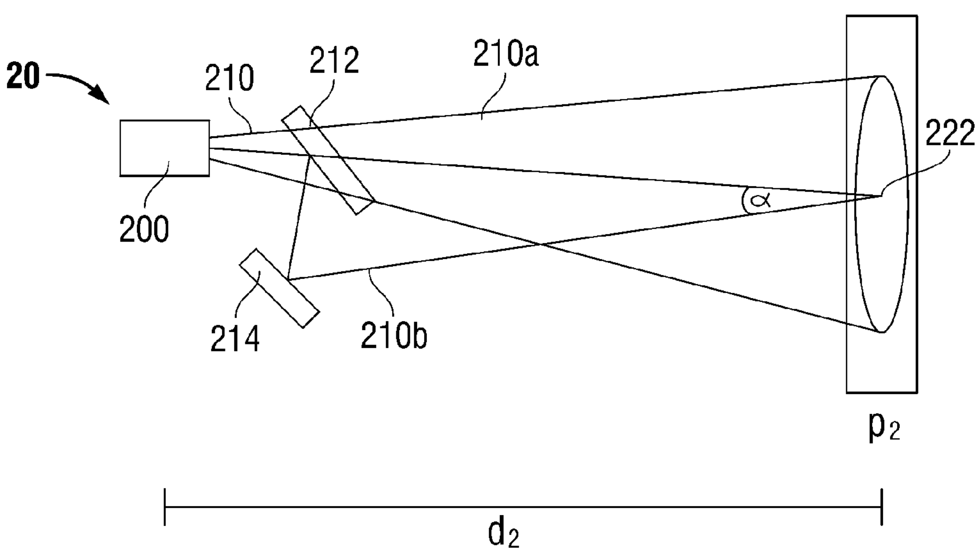
20
210
212
210a
222
200
α
214
210b
p_2
d_2

FIG. 4

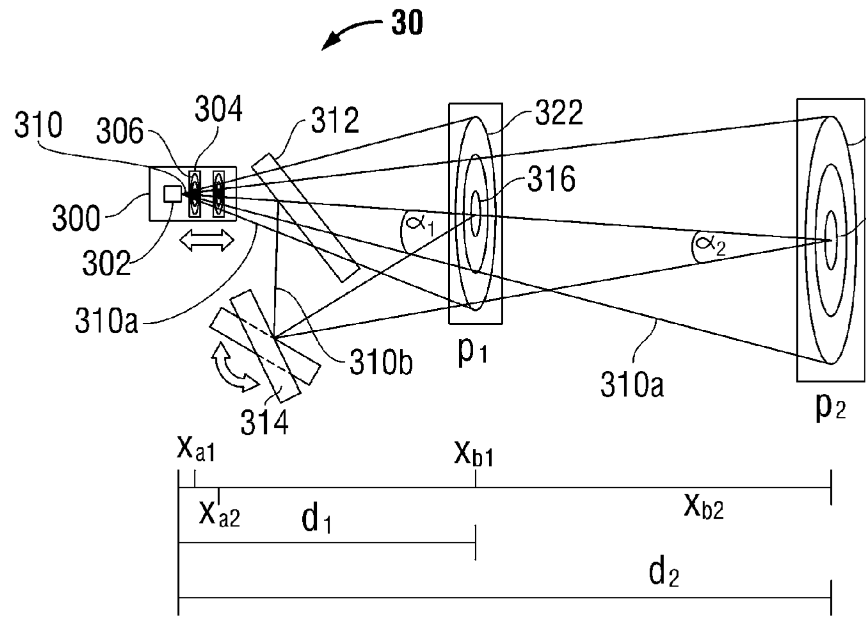
30
310
306
304
312
322
316
300
302
310a
310b
314
p1
310a
322
316
p2
α1
α2
xa1
xb1
x'a2
d1
xb2
d2

FIG. 5

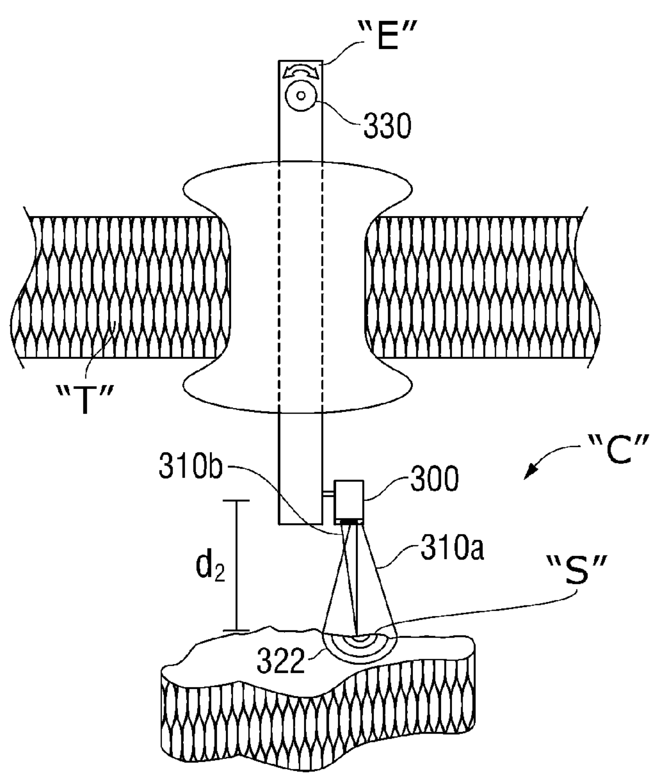
"E"
330
"T"
"C"
310b
300
d2
310a
"S"
322

FIG. 6

METHODS UTILIZING TRIANGULATION IN METROLOGY SYSTEMS FOR IN-SITU SURGICAL APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 13/448,429, filed Apr. 17, 2012, which claims the benefit of and priority to U.S. Provisional Patent Application No. 61/487,750, filed May 19, 2011, the entire disclosure of which is incorporated by reference herein.

BACKGROUND

1. Technical Field

The present disclosure relates to a method for measuring a dimension of a target site. More particularly, the present disclosure relates to a method of triangulation for creating an image of a predetermined size for use in measuring a dimension of a target site.

2. Background of the Related Art

Minimally invasive surgery, e.g., laparoscopic, endoscopic, and thoroscopic surgery, has many advantages over traditional open surgeries. In particular, minimally invasive surgery eliminates the need for a large incision, thereby reducing discomfort, recovery time, and many of the deleterious side effects associated with traditional open surgery.

The minimally invasive surgeries are performed through small openings in a patient's skin. These openings may be incisions in the skin or may be naturally occurring body orifices (e.g., mouth, anus, or vagina). In general, insufflation gas is used to enlarge the area surrounding the target surgical site to create a larger, more accessible work area.

During minimally invasive procedures, it is often difficult for a surgeon to determine sizes of various organs, tissues, and other structures in a surgical site. Various in-situ surgical metrology methods exist for measurement in a surgical site. Such methods require many moving parts and projection images that change size and/or focus quickly as projectors move in or out of a surface of projection. A continuing need exists for in-situ surgical metrology methods that operate with a stable focus and no moving parts.

SUMMARY

A first metrology method includes the steps of projecting a first image and a second image, aligning the first image and the second image to form an aligned image of a known size by moving an instrument towards and away from a target object, and determining a dimension of a target object by comparing the aligned image to the target object. The aligned image may include aligned circles. The aligned image may include a single point aligned with a center point of a circle. The projecting of at least one of the first image and second image may be achieved by a point source projector. A single beam may be split to project the first image and the second image.

A second metrology method includes the steps of projecting a first image and a second image, aligning the first image and the second image to form an aligned image of a known size by synchronously adjusting a zoom factor for projecting the first image and an angle for projecting the second image, and determining a dimension of a target object by comparing the aligned image to the target object. The aligned image may include aligned circles. The aligned image may include a single point aligned with a center point of a circle. The projecting of at least one of the first image and second image may be achieved by a point source projector. A single beam may be split to project the first image and the second image.

In other embodiments the metrology system may be a standalone device, while projected pattern is observed through a separate endoscope.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other aspects, features, and advantages of the present disclosure will become more apparent in light of the following detailed description when taken in conjunction with the accompanying drawings in which:

FIG. **1** is a side, schematic view of a metrology system according to the principles of the present disclosure;

FIG. **2** is a side, schematic view of a projector of the metrology system of FIG. **1**;

FIG. **3** is a side, perspective view of a method of use of the metrology system of FIG. **1**;

FIG. **4** is a side, schematic view of a metrology system according to another embodiment of the present disclosure;

FIG. **5** is a side, schematic view of a metrology system according to another embodiment of the present disclosure; and

FIG. **6** is a side, perspective view of a method of use of the metrology system of FIG. **5**.

DETAILED DESCRIPTION

Particular embodiments of the present disclosure are described hereinbelow with reference to the accompanying drawings; however, it is to be understood that the disclosed embodiments are merely exemplary of the disclosure and may be embodied in various forms. Well-known functions or constructions are not described in detail to avoid obscuring the present disclosure in unnecessary detail. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the present disclosure in virtually any appropriately detailed structure.

Like reference numerals may refer to similar or identical elements throughout the description of the figures. As shown in the drawings and described throughout the following description, as is traditional when referring to relative positioning on a surgical instrument, the term "proximal" refers to the end of the apparatus which is closer to the user and the term "distal" refers to the end of the apparatus which is farther away from the user. The term "clinician" refers to any medical professional (i.e., doctor, surgeon, nurse, or the like) performing a medical procedure involving the use of embodiments described herein.

As seen in FIG. **1**, a metrology system **10** according to an embodiment of the present disclosure is illustrated. Metrology system **10** utilizes projectors **100** for projecting light beams **110** at intersecting angles. Projectors **100** include a projector **100***a* and a projector **100***b*. Some embodiments may utilize more than two projectors **100**. Other embodiments may only have one projector **100**, as will be described in greater detail hereinbelow. In metrology system **10**, projector **100***a* and projector **100***b* are substantially identical and project substantially identical light beams **110***a*, **110***b*, respectively.

Light beams **110** form an image **120** including an image **120***a* from light beam **110***a* and an image **120***b* from light beam **110***b*. Images **120***a*, **120***b* substantially align to form a substantially aligned image **122** having a predetermined size on an image plane p_2 at a distance d_2 from point sources **102** (FIG. **2**) of projectors **100**. Image plane p_2 is the only image plane on which images **120***a*, **120***b* align. On an image plane

p_1 at a distance d_1 less than distance d_2 from point sources **102** of projectors **100**, an unaligned image **121** is formed. Likewise, on an image plane p_3 at a distance d_3 greater than distance d_2 from point sources **102** of projectors **100**, an unaligned image **123** is formed. Distance d_2 may be calculated geometrically using a distance between point sources **102** and angles of projectors **100**. Distance d_2 may also be determined experimentally. Similarly, the predetermined size of aligned image **122** may be determined geometrically or experimentally.

Images **120***a*, **120***b* may be any shapes appropriate for determining an alignment of thereof. For example, images **120***a*, **120***b* may be circles that concentrically overlap on image plane p_2. Images **120***a*, **120***b* have uniformly spaced markings. In other embodiments, an endoscope or other device may provide uniformly spaced markings. When image **122** is formed, the uniformly spaced markings have a predetermined distance therebetween to assist in determining a measurement of a dimension on image plane p_2. The predetermined distance of the uniformly spaced markings may be determined geometrically or experimentally. Although images **120***a*, **120***b* are substantially identical in metrology system **10**, other embodiments may have differing shapes of images **120***a*, **120***b*.

As seen in FIG. **2**, a projector **100** includes a point source **102** and a mask **104**. Point source **102** emits a light beam **110**. Various embodiments of point source **102** include a laser diode, a light-emitting diode, and a lens for shaping a beam of light. Mask **104** is positioned between point source **102** and the target site. Mask **104** has a pattern **106** disposed thereon in a shape of a desired image **120**, such as a series of concentric, uniformly spaced circles. Light beam **110** may be collimated for increased sharpness of image **120**. Light beam **110** is partially blocked upon incidence with mask **104**. A portion of light beam **110** that passes through mask **104** forms a magnified pattern **116** as a portion of image **120**.

A magnification factor of pattern **106** to pattern **116** is calculated according a formula: $M=1+x_b/x_a$, where M is the magnification factor, x_a is a distance between point source **102** and mask **104**, and x_b is a distance between mask **104** and the target site. Accordingly, image **120** may be enlarged when x_b is increased or x_a is decreased. Image **120** may shrink upon an increase of x_a or a decrease of x_b. Mask **104** may be translated with respect to the target site to increase or decrease x_a and x_b. Metrology system **10** may be translated to increase or decrease x_b. Point source **102** is sufficiently small for edges of image **120** to remain substantially sharp as a size of image **120** changes.

A method of use of metrology system **10** will now be described. As seen in FIG. **3**, metrology system **10** may be attached to a distal end of an endoscope "E". Endoscope "E" is inserted into a body cavity "C" through an opening in a tissue "T". Endoscope "E" may be inserted through a seal anchor "R" positioned in the opening in tissue "T". Projectors **100** project image **120** onto a target site "S" within cavity "C". A clinician may observe image **120** through endoscope "E". If images **120***a*, **120***b* are not aligned, endoscope "E" is translated distally or proximally until point sources **102** of projectors **100** are at distance d_2 from target site "S". Once aligned image **122** is formed on target site "S", the predetermined size of aligned image **122** and the predetermined distance of the uniformly spaced markings thereon may be used to measure a dimension of target site "S". A dimension of target site "S" is measured by visually inspecting and counting a number of uniformly spaced markings appearing along the dimension of target site "S". The number of uniformly spaced markings is multiplied by the predetermined distance therebetween to calculate the measure of the dimension of target site "S".

Turning to FIG. **4**, a metrology system in accordance with an alternate embodiment of the present disclosure is generally designated as **20**. Metrology system **20** is similar to metrology system **10** and thus will only be discussed as necessary to identify the differences in construction and operation thereof.

Metrology system **20** has a projector **200**, a splitter **212**, and a reflector **214**. Projector **200** is substantially identical to projector **100** (FIG. **2**) and projects a light beam **210**. Splitter **212** splits light beam **210** into light beams **210***a*, **210***b*. Embodiments of splitter **212** include prisms and mirrors. Light beam **210***a* passes through splitter **212**. Light beam **210***b* is reflected by splitter **212** onto reflector **214**. Reflector **214** reflects light beam **210***b* at an angle α for intersection with light beam **210***a*.

Light beams **210** form a substantially aligned image **222** on an image plane p_2 at a distance d_2 from a point source of projector **200**. Image plane p_2 is the only image plane on which a substantially aligned image is formed. Light beams **210** project a pattern having uniformly spaced markings onto image plane p_2. Distance d_2, a distance of the uniformly spaced markings, and a size of aligned image **222** may be determined geometrically or experimentally.

Light beams **210** produce images of any shapes appropriate for determining an alignment of thereof. In some embodiments, a total overlap of certain elements of the images of light beams **210** may not occur due to light beam **210***a* travelling a shorter total distance than light beam **210***b* to reach image plane p_2. In such embodiments, an alignment of a point or a line may be an ideal indicator of alignment. For example, light beam **210***a* may project a circle with a center point, and light beam **210***b* may project a single point for aligning with the center point of the image projected by light beam **210***a*.

A method of use of metrology system **20** is substantially identical to the method of use of metrology system **10** described hereinabove.

Turning to FIG. **5**, a metrology system in accordance with an alternate embodiment of the present disclosure is generally designated as **30**. Metrology system **30** is similar to metrology system **20** and thus will only be discussed as necessary to identify the differences in construction and operation thereof.

Metrology system **30** includes a projector **300**, a splitter **312**, a reflector **314**, and an actuator **330** (FIG. **6**). Projector **300** includes a point source **302** and a mask **304**. Mask **304** is a distance x_{an} away from point source **302** and distances x_{bn} away from image planes p_n. Point source **302** emits a light beam **310** that passes through a pattern **306** on mask **304**. Splitter **312** splits light beam **310** into light beams **310***a*, **310***b*. Light beam **310***a* passes through splitter **312** and forms a first image on an image plane p_n. Light beam **310***b* is reflected by splitter **312** onto reflector **314**. Reflector **314** is rotatable to reflect light beam **310***b* at any of angles α_n onto image planes p_n to form a second image. The first image and the second image form a substantially aligned image **322** on an image plane p_n having a distance d_n from point source **302** when reflector **314** reflects light beam **310***b* at a particular angle α_n. For each image plane p_n, only angle α_n provides for a projection of substantially aligned image **322**. Substantially aligned image **322** has a magnified pattern **316** thereon. Magnified pattern **316** is a magnification of pattern **306** and includes uniformly spaced markings thereon having a predetermined distance on image plane p_n.

Actuator **330** is operably coupled to mask **304** and reflector **314**. A manipulation of actuator **330** rotates reflector **314**, thus changing an angle α_n and an image plane p_n on which aligned image **322** is formed. Actuator **330** translates mask

304 a distance to maintain a predetermined size of image **322**. The translation of mask **304** and the rotation of reflector **314** are synchronous upon a manipulation of actuator **330**. A relationship between the translation of mask **304** and the rotation of reflector **314** is described according to the following formulas:

$$d_2/d_1=\tan(\alpha_1)/\tan(\alpha_2)=M_1/M_2$$

$$M=1+x_b/x_a$$

$$d=x_a+x_b$$

In the formulas above, the values of d_1, α_1, and M_1 respectively represent an initial distance d_n, angle α_n, and magnification M_n of system **30**. The values of d_2, α_2, and M_2 respectively represent a resulting distance d_n, angle α_n, and magnification M_n of system **30** after actuator **330** is manipulated.

A method of use of metrology system **30** is similar to the method of use of metrology system **10** described hereinabove. As seen in FIG. **6**, metrology system **30** is attached to a distal end of an endoscope "E". Endoscope "E" is inserted into a body cavity "C" through an opening in a tissue "T". Projector **300** projects light beams **310***a*, **310***b* onto a target site "S" within cavity "C". A clinician may observe an image formed by light beams **310***a*, **310***b* through endoscope "E". If substantially aligned image **322**, is not formed on target site "S", actuator **330** is rotated until substantially aligned image **322** is formed on target site "S". The predetermined size of substantially aligned image **322** and the uniformly spaced markings of magnified pattern **316** may then be used to measure a dimension of target site "S".

It should be understood that the foregoing description is only illustrative of the present disclosure. Various alternatives and modifications can be devised by those skilled in the art without departing from the disclosure. Accordingly, the present disclosure is intended to embrace all such alternatives, modifications and variances. The embodiments described with reference to the attached drawing figs. are presented only to demonstrate certain examples of the disclosure. Other elements, steps, methods and techniques that are insubstantially different from those described above and/or in the appended claims are also intended to be within the scope of the disclosure.

What is claimed is:

1. A metrology method comprising:

projecting a first image and a second image on an image plane;

aligning the first image and the second image on a target site different from the image plane; and

measuring a dimension of the target site by counting uniformly spaced markings formed by the aligned first and second images.

2. The metrology method according to claim **1**, wherein aligning the first image and the second image on the target site includes forming an aligned image of a known size.

3. The metrology method according to claim **1**, wherein measuring the dimension of the target site includes counting uniformly spaced circles formed by the aligned first and second images.

4. A metrology method comprising:

projecting first and second images on an image plane;

aligning the first image and the second image on a target site different from the image plane by synchronously adjusting a zoom factor for projecting the first image and an angle for projecting the second image; and

measuring a dimension of the target site by visually comparing the aligned first and second images with the target site.

5. The metrology method according to claim **4**, wherein projecting the first and second images includes projecting a light beam through a pattern on a mask.

6. The metrology method according to claim **4**, wherein measuring the dimension of the target site includes counting uniformly spaced markings formed by the aligned first and second images.

7. The metrology method according to claim **4**, wherein aligning the first image and the second image on the target site includes forming an aligned image of a known size.

8. The metrology method according to claim **4**, wherein projecting the first and second images on the image plane includes projecting at least one of the first image and the second image by a point source projector.

9. The metrology method according to claim **4**, wherein projecting the first and second images includes splitting a single beam.

10. The metrology method according to claim **4**, wherein projecting the first and second images includes projecting the first and second images using two projectors.

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